eRD101 - mRICH R&D for particle identification (PID) at EIC

X. He[1] and M. Contalbrigo[2]

[1]*Georgia State University, Atlanta, GA 30303*
[2]*INFN, Sezione di Ferrara, 44100 Ferrara, Italy*

September 2, 2021

1 Introduction

The design goal of a modular and compact RICH (mRICH) detector is to meet the EIC physics requirements for K/π separation in momentum range from 2 to 8 GeV/c and the physical constraints of the EIC experiments. It also provides excellent e/π for momentum up to 2 GeV/c.

The novel design of mRICH consists of four components. A block of aerogel serves as the Cherenkov radiator. Immediately followed by an acrylic Fresnel lens, which focuses the ring image and acts as a UV filter. A pixelated optical sensor is located in the image plane, and the gap between the lens and the image plane is bounded by four flat mirrors. mRICH has been identified as the baseline PID detector in the electron endcap of EIC detector concept in EIC Yellow Report

The working principles of mRICH have been tested and verified at the Fermilab test beam facility. The first mRICH prototype was constructed in 2015 and was successfully tested at Fermilab in 2016. The results from the first beam test have been published in NIM A (2017). An improved mRICH prototype was developed in 2017 with a longer Fresnel focal length ($f = 6''$) and a new holder box made of aluminum plates for the mRICH optical component, as shown in Fig. 1. The second mRICH beam test was performed in 2018 with the new prototype and new photosensors of smaller pixel size (Hamamatsu H13700, 3 mm $\times$ 3 mm) in comparison with the sensors (6 mm $\times$ 6 mm) used in the first test. In June of 2021, the very first beam test of a LAPPD was performed at Fermilab for identifying potential single-photon sensors for mRICH. At the time of preparing this proposal, an effort is being carried out at Jefferson Lab (JLab) for measuring single-photon angle resolution using secondary electrons (1 to 6 GeV/c) in Hall D. The data taking of this beam test will start in early September of 2021. This is a low-risk activity with substantial benefits and moderate cost.

The main objectives of this proposal are twofold: (a) continuing mRICH performance characterization and improving mRICH design for realistic installation with maximization of acceptance; and (b) mitigating the risk factors of mRICH.

The member institutions of mRICH team include ANL (Junqi Xie), BNL (Alexander Kieslev et. al.), Duke University (Zhiwen Zhao et. al.), Georgia State University (Xiaochun He et. al), INFN/Ferarra (Marco Contalbrigo et. al.), University of South Carolina (Yordanka Ilieva), University of Virginia (Kondo Gnanvo).

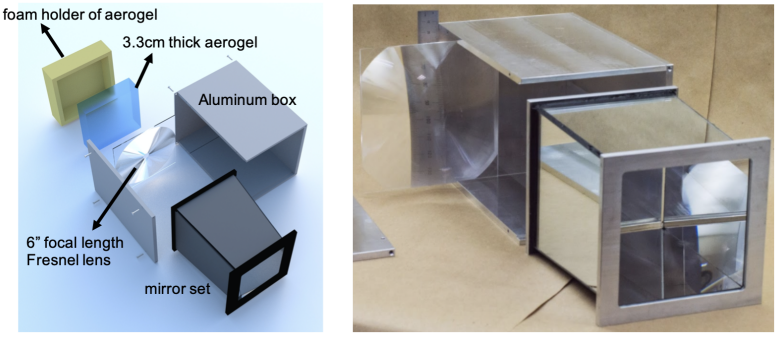

Figure 1: The second mRICH prototype design 3D rendering (left) and the partial detector assembly (right). Optical components only are shown.

2 Proposed mRICH R&D Activities in FY22

The activities we propose for FY22 are very consistent with our plan which was outlined in the eRD14 (PID Consortium) proposal for FY21. In addition, following the active participation in the preparation of EIC detector proposals, mRICH team has identified and prioritized the following R&D tasks for FY22:

- **Data Analysis** This effort includes analyzing the mRICH beam test data at JLab (to be available near the end of September 2021) and finishing up the data analysis from the 2nd mRICH beam test at Fermilab. This task will be led by a postdoc (Deepali Sharma) at GSU with support from Duke (Zhiwen Zhao, Bishnu Karki), INFN (Marco Contalbrigo), JLab (Sergey Furletova), and UVA (Kondo Gnanvo, Xinzhan Bai) groups.

- **GEANT4 Simulation** Realistic detector simulation of mRICH has been a vital tool throughout the process of mRICH development. The planned simulation efforts have two components. The first is to fine tune the detector description in GEANT4 to match the mRICH hardware configuration to aid the data analysis both for the JLab test and the Fermilab test. The second effort is to study the mRICH array in the context of EIC detector concept (both for ECCE and ATHENA, led by Murad Sarsour at GSU). The goal of the study is to quantify acceptance and efficiency in combination of tracking detectors. This effort will be led by GSU group.

- **mRICH Optical Components** A functioning mRICH includes an aerogel block (a RICH radiator), an acrylic Fresnel lens (for forming a sharper and smaller ring image) and a mirror set (preventing loss of signal photons). Acquiring, characterizing, maintaining aerogel blocks are the most challenging efforts for mRICH. This effort will be led by INFN group as it was done in eRD14. It is noted that INFN group also leads the eRD102 R&D and has consolidated experience in aerogel and mirror for Cherenkov applications. A synergic R&D on aerogel and mirrros will minimize the overall cost of the project. In parallel, we also want to develop an optical characterization system to measure the lens and mirror properties for mRICH in order to study and minimize the contribution to single photon angle resolution. We think that these efforts could be carried out by GSU students as student projects and supported with internal sources at GSU.

- **Engineering Design** Over the course of eRD14 program, our effort was focused on studying the performance of a single mRICH module (see Fig. 1). It is the time to consider new engineering design of mRICH optical component assembly and the support structure for optimizing the acceptance and system integration. GSU physics machine shop played a key role in making the mechanical components for building mRICH prototypes and will continue supporting small scale mechanical design and component fabrication for new prototypes. This will be an in-kind contribution to the

Table 1: List of major budget request in FY22.

Category	**Qty**	**Cost**
Postdoc at GSU	1	\$60k
Postdoc at INFN	1	\$40k
Engineering support	2-month	\$20k
Aerogel purchase	10	\$10k
Readout	8	\$20k
Mirrors and Fresnel lens	4 sets	\$2k
GEM tracker and readout	1	\$15k
Material supplies		\$3k

mRICH R&D from GSU. We rquest \$20k to support engineers from other institutions to work on the design.

- **New mRICH Prototype** Preparation for an mRICH performance test of K/π and e/π separation at Fermilab with tracking capability in F23. We expect to construct a new mRICH prototype by the end of FY22 and to build a complete test setup at GSU including a data acquisition system and a pair of GEM tracker chambers to be purchased from CERN. This setup could serve either as a permanent development station using cosmic rays or a ready-to-go setup for beam tests. In collaboration with the INFN group, an independent readout of the reference H13700 detectors should be realized to avoid conflicts like the one emerging in FY21 due to the electronics sharing with dRICH. Kondo Gnanvo from UVA will help the GEM chamber assembly for mRICH.

The estimated funding requests for FY22 are listed in Table 1.

3 Proposed mRICH R&D Activities in FY23/24

The identified R&D activities in FY23/24 will follow the success of the FY22 plans. We will be focusing on realistic beam tests with newly identified photosensors and readout. The general plan includes the following:

- mRICH performance tests of K/π and e/π separation in FY23 with optimized aerogel and prototype layout.
- mRICH tests with new photosensors in FY24. The expected focus will be using new generation of LAPPD (10cm $\times$ 10cm formfactor) and SiPM sensors with properly engineered cooling.

As it was done in past, the success of mRICH development will depend on team effort with synergies among the members from participating institutions and beyond. It is our intention to closely follow the development in eRD110 and to coordinate joint mRICH beam test. As an example, Kondo Gnanvo from UVA has expressed strong interest in studying LAPPD for mRICH using capacitive pad's readout.

Our projected funding requests include support for purchasing photosensors, readout electronics, travel, and manpower is \$150k per year in FY23 and FY24.